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DIRC, the Particle Identification System for BABAR*

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Representing the BABAR-DIRC Collaboration ‡

Abstract

The DIRC, a novel type of Cherenkov ring imaging device, is the primary hadronic particle identification system for the *BABAR* detector at the asymmetric B-factory, PEP-II at SLAC. *BABAR* began taking data with colliding beams mode in late spring 1999. This paper describes the performance of the DIRC during the first 16 months of operation.

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The primary physics goal of the BaBar experiment [1] at the SLAC Pep-II asymmetric e^+e^- collider is to study CP violation in the B^0 meson system produced in $\Upsilon(4S)$ decays. At the $\Upsilon(4S)$, Pep-II collides 9 GeV electrons on 3.1 GeV positrons at $\beta\gamma(lab) = 0.56$. The study of CP-violation in hadronic final states of the B meson system requires the ability to tag the flavor of one of the B mesons via the cascade decay $b \to c \to s$, while fully reconstructing the final state of the other B. The momenta of the kaons used for flavor tagging extend up to about 2 GeV/c, with most below 1 GeV/c. On the other hand, pions from the rare two-body decays $B^0 \to \pi^-\pi^+(K^-\pi^+)$ must be well-separated from kaons, and have momenta between 1.5 and 4.5 GeV/c where high momentum tracks are srongly correlated with forward polar angles due to the c.m. system boost. Since the BaBar inner drift chamber tracker can provide π/K separation up to approximately 700 MeV/c, an additional dedicated particle identification system is required that must perform well over the range of 700 MeV/c to about 4 GeV/c.

The system being used in BaBar is a novel type of ring imaging Cherenkov detector, called the Dirc [2] (Detection of Internally Reflected Cherenkov light), which has been described in detail elsewhere [3]. Briefly, it uses 4.9 m long, rectangular bars made from synthetic fused silica as Cherenkov radiator and light guide. A charged particle with velocity v, traversing the fused silica bar with index of refraction n (~ 1.473), generates a cone of Cherenkov photons of half-angle θ_c with respect to the particle direction, where $\cos\theta_c = 1/\beta n$ ($\beta = v/c$, $c =$ velocity of light). For particles with $\beta \approx 1$, some photons always lie within the total internal reflection limit, and are transported efficiently to either one or both ends of the bar, depending on the particle incident angle. Since the bar has a rectangular cross section and is made to optical precision, the magnitude of the Cherenkov angle is conserved during the reflection at the radiator bar surfaces. The photons are imaged via "pin-hole" focussing by expanding through a standoff region filled with 6000 litres of purified water onto an array of 10752 densely packed photomultiplier tubes placed at a distance of about 1.2 m from the bar end. Imaging in the BaBar Dirc occurs in three dimensions, by recording the location and the time at which a given PMT is hit. The expected single photon Cherenkov angle resolution is about 9 mrad, dominated by a geometric term that is due to the sizes of bars, PMTs and the expansion region, and a chromatic term from the photon production. The accuracy of the time measurement is limited by the intrinsic 1.5 ns transit time spread of the PMTs.

In the absence of correlated systematic errors, the resolution ($\sigma_{C,track}$) on the track Cherenkov angle should scale as

$$\sigma_{C,track} = \sigma_{C,\gamma}/\sqrt{N_{pe}} \ , \tag{1}$$

where $\sigma_{C,\gamma}$ is the single photon Cherenkov angle resolution, and N_{pe} is the number of photons detected. The average single photon resolution obtained for photoelectrons from di-muon events, $e^+e^- \to \mu^+\mu^-$, is 10.2 mrad, about 10% worse than the expected value. The time resolution obtained is 1.7 ns, close to the single-photon resolution of the PMTs.

The number of photoelectrons per track, shown in Fig. 1, varies from a minimum of about 20 for small dip angles at the center of the barrel to well over 50 at large dip angles. This is in good agreement with the value expected from the Monte Carlo simulation at all

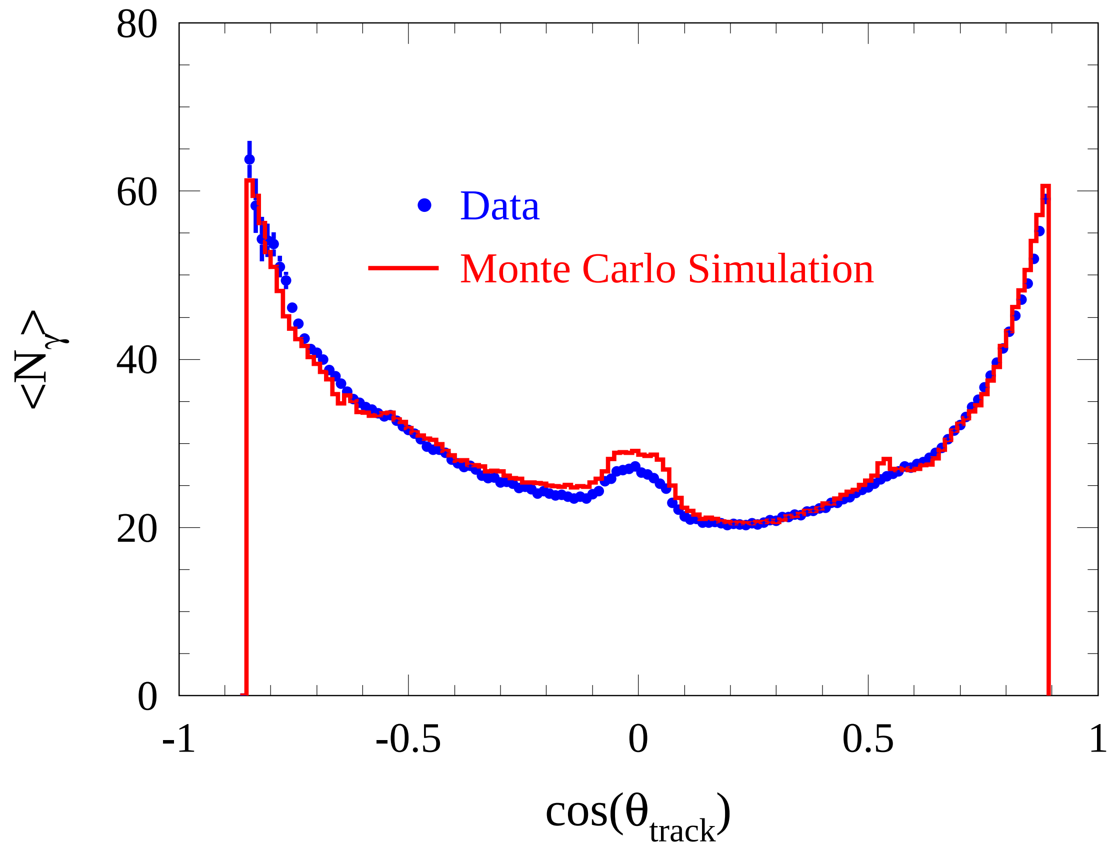

Figure 1: Number of detected photoelectrons *vs.* track dip angle $\theta_{\rm track}$ for di-muon events.

angles. This spectrum also demonstrates a very useful feature of the DIRC in the *BABAR* environment – the performance improves in the forward direction, as is needed to cope with the angle-momentum correlation of particles from the boost.

With the present alignment, the typical track Cherenkov angle resolution for di-muon events is shown in Fig. 2 to be 2.8 mrad. This is about 25% worse than the 2.2 mrad expected from simulation. From the measured single track resolution resolution *vs.* momentum in di-muon events and the difference between the expected Cherenkov angles of charged pions and kaons, the pion-kaon separation power of the DIRC can be inferred. The present separation between kaons and pions at 3 GeV/c is about 3.8 σ, approximately 10% worse than predicted by the Monte Carlo simulation, and is expected to improve with advances in tracking and detector alignment.

In summary, the DIRC was successfully commissioned, attained performance rather close to that expected from Monte Carlo, and has played a significant role in almost all *BABAR* analyses presented at this conference. The DIRC has been robust and stable and, almost 2 years after installation, about 99.7% of all PMTs and electronic channels are still operating with nominal performance.

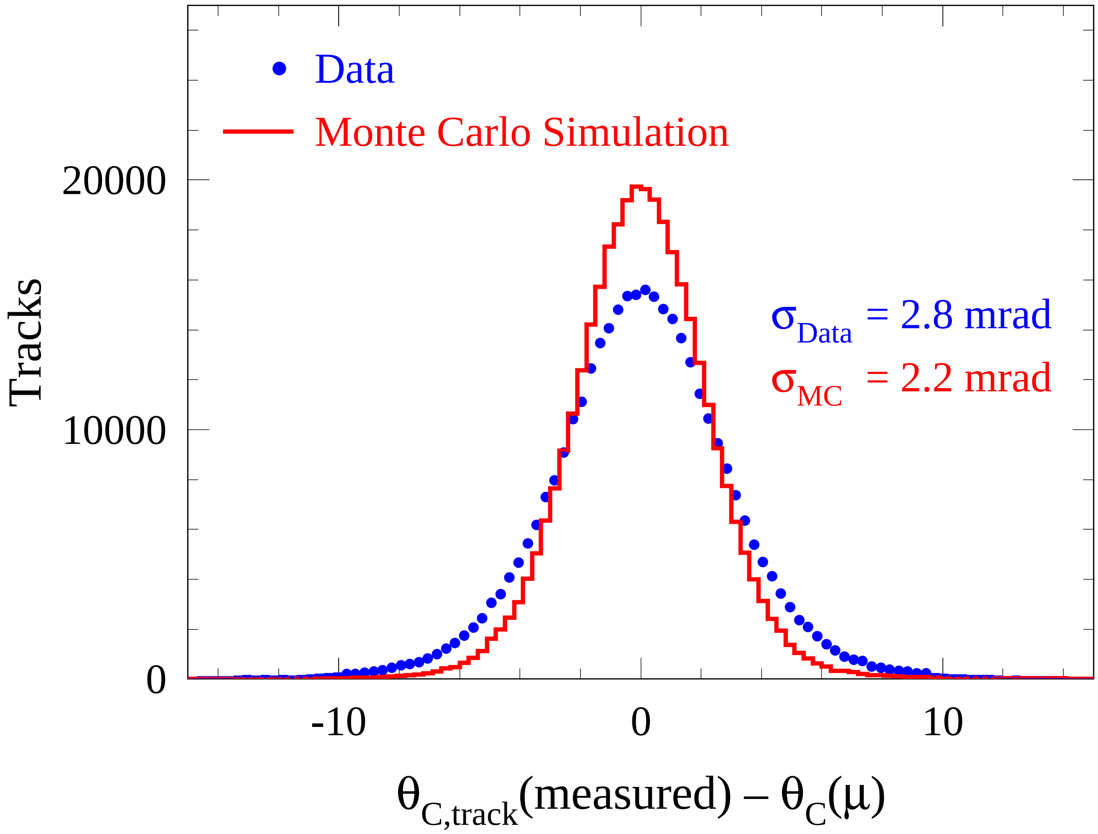

Figure 2: Resolution of the reconstructed Cherenkov polar angle per track for di-muon events.

References

[1] The *BaBar* Collaboration, "'The *BaBar* Physics Book," SLAC-R-504 (1998).

[2] B. N. Ratcliff, SLAC-PUB-6067 (1993);
P. Coyle et al., *Nucl. Inst. Meth.* A **343** (1994) 292.

[3] The *BaBar* Collaboration, "The *BaBar* Detector,"
to be published in *Nucl. Inst. Meth.* A.